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Development of LMS-Based Teaching Materials for the Preparation of Chemistry Lab Courses: Aspects for the Design of Conducive Learning Environments

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Abstract

The utilization of learning management systems (LMS) as media for the preparation of chemistry laboratory courses has turned out to be a valuable tool for the training of manual skills. For the design of such LMS-based preparatory courses, a large variety of media tools is available for the most E-learning platforms such as ILIAS, Stud.IP or Moodle including text, (animated) pictures and videos. Additionally, numerous of interactive tasks can be applied for the construction of formal and informal tests, which are suited to evaluate chemistry specific knowledge, such as the application of chemical and mathematical formulas or questions on the processing of chemical working techniques. However, the development of a LMS-based environment which is conducive to learning requires the consideration of diverse design principles based on the Cognitive Load Theory of Multimedia Learning (CTML) which will be presented in some detail. Besides, we will show an example of a LMS-based environment about gas laws (Boyle-Mariotte, Gay-Lussac and Amontons) in which these principles are applied.

1. Introduction

Multimedia learning environments in chemistry teaching become increasingly relevant. Modern learning management systems like ILIAS, Stud.IP or Moodle enable teachers to create individual teaching materials which include interactive components. Particularly, the mediation of research methods such as crystallography or NMR benefits from the utilization of such LMS-based environments [1].

However, the great variety of the possibilities for preparing electronic teaching material requires the consideration of didactical design aspects for the on-screen design of learning units. With respect to the preparation of lab chemistry courses, research indicates that it is helpful for freshmen to provide a video or an animation about the conduction of an experiment before they enter the lab and conduct the respective experiment on their own [2]. Therefore, design principles for videos and animations should be especially concerned when these courses are developed.

Within a cooperation project between the Chemistry Didactics of the Georg-August-University Göttingen and the PHYWE Company, a learning platform called *Curriculab* was developed using the learning managements system ILIAS [3]. This platform enables the impartment of theoretical contents as well as learning units for the preparation of lab chemistry courses.

In our contribution, we will describe the structure of learning units on the preparation of experiments on the Ideal Gas Law in our *Curriculab* and focus on design principles for the videos and animations that are implemented in these units.

2. Structure of Learning Units on the Ideal Gas Law

In cooperation with the PHYWE Company, four multimedia based teaching units were developed which support the conduction of the respective experiments and deepen the acquired knowledge about the Ideal Gas Law. These four teaching units have a similar structure and each focus on a law which is related to the Ideal Gas Law. By exposing themselves to the teaching units, students are prepared to conduct an experiment which is meant to proof the respective law. Furthermore, the units help them to evaluate the experiments and comprehend the relevance of the laws in everyday life as well as in science history. Figure 1 exemplarily shows the structure of one of the teaching units.

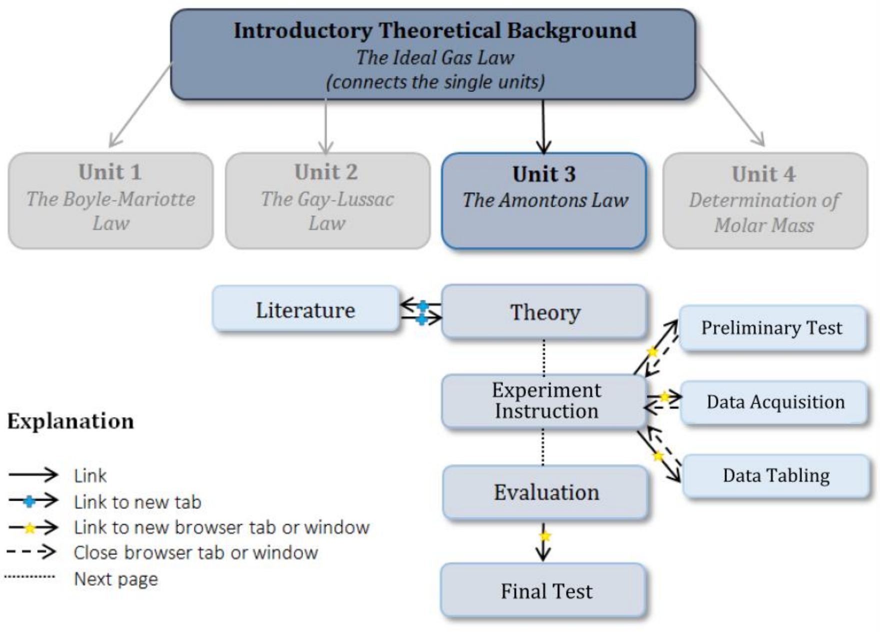

Figure 1. Structure of the teaching units on Ideal Gas Law in the *Curriculab*.

First, the theory section gives short introduction to the respective topic and intendeds to motivate the students by providing interesting applications of the law to everyday life phenomena. Second, there is an instruction to the respective experiment which is meant to be conducted by the students. This instruction consists of two parts:

(a) A video demonstrating the distinct steps during the experiment and also including labels of the required devices for the experiment as well as safety aspects and

(b) a corresponding instruction of the experiment in written form with figures of the experimental set-up, shown in Figure 2.

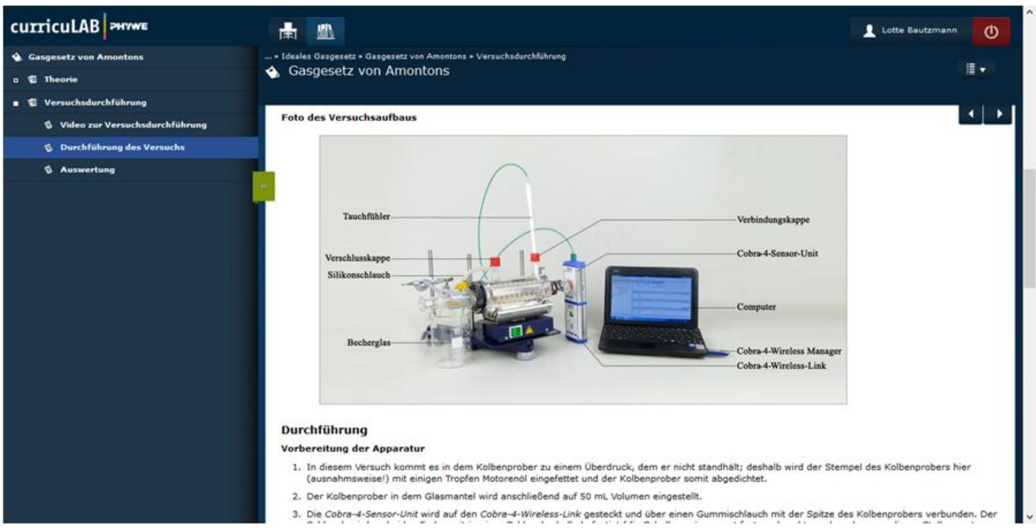

Figure 2. Screenshot of the written instruction and figures of the experimental setup.

Afterwards, the student is directed to a preliminary test which intends to contribute to the success of the experiment and to avoid dangerous situations. Therefore, specific questions to the experimental procedure are asked. To ensure the validity of the test, the so-called 'safe-exam-browser' option is used, which prohibits the opening of further websites and applications. After a successful completion of the preliminary test, the experiment can be conducted. During this, the data is acquainted as well as tabled automatically two separate tabs by a program called *measure* developed by the PHYWE Company [4]. Finally, students are asked to evaluate the experiment by graphing the data and interpreting the graphs which are meant to proof the respective law.
At the end of each unit, students have to pass a final test with questions about the evaluation of the experiment. An example question in the learning unit on the Gas Law of Amontons is given in Figure 3.

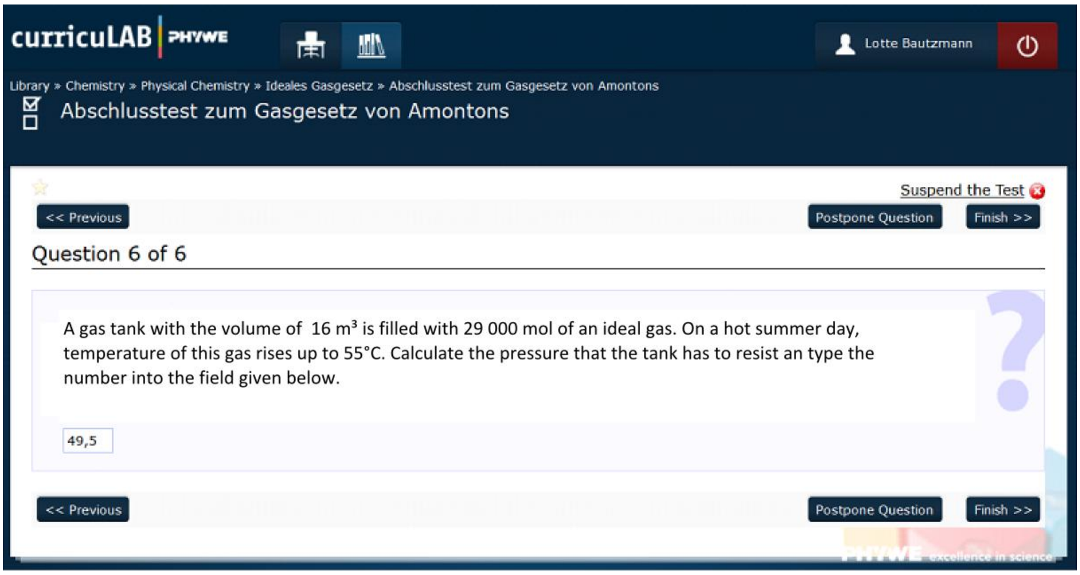

Figure 3. Example question in the learning unit on the Gas Law of Amontons.

3. Design Principles for Videos and Animations Implemented in the Learning Units

For the creation of videos and animations for the learning units, the design principles according to Mayer are considered in the development of multimedia learning environments. These principles were deduced from the Cognitive Theory of Multimedia Learning (CTML) and are based on wide empirical evidence [5]. Special focus was placed on the following principles: the Segmenting Principle (1), the Modality Principle (2), the Principle of Temporal Contiguity (3) and the Redundancy Principle (4). Additionally, the Presentation Sequence Principle (5) by Niegemann et. al. was considered [6].
Due to (1), the length of the created videos was limited to three minutes and the students were able to control the progress of the videos and animations. In respect of (2) and (3), explications of animations and videos were realized by spoken comments instead of written ones and the comments were presented simultaneously to the respective animations or videos. Regarding (4), a presentation of a combination of written text, spoken text and videos or animations was avoided. Lastly, according to (5) the video is shown first, followed by the figures to the experimental set-up and finally the experiment's instructions in written form.

4. Conclusion and Outlook

In this contribution, the structure of an E-learning module concerning the Ideal Gas Law was described, which was developed within a cooperation project between the PHYWE Company and the Department of Chemistry Didactics of the Georg-August-University Göttingen. Apart from that, the design principles for the videos and animations implemented in the learning units were presented.

The learning module described above can be applied for both teaching in school and in university. Experiences reveal that particularly pupils and university freshmen have difficulties in dealing with lab devices and chemicals; especially these learning units show great potential supporting these students in their lab work.

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